RESEARCH MANAGEMENT

A PUBLICATION OF THE
INDUSTRIAL RESEARCH INSTITUTE

AUTUMN 1959
Volume II, Number 3

INTERSCIENCE PUBLISHERS • NEW YORK • LONDON

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Published quarterly, one volume per year, by Interscience Publishers, Inc. and the Industrial Research Institute, Inc.

Publication Office, 20th and Northampton Streets, Easton, Pa. Editorial and Circulation Offices at 250 Fifth Avenue, New York 1, New York. Second-class mail privileges authorized at Easton, Pennsylvania.

SUBSCRIPTIONS: Price per volume: $7.50; to IRI members, $6.50. Foreign postage, $0.50 per volume. IRI subscriptions should be placed through the Industrial Research Institute, Inc., 100 Park Avenue, New York 17, New York. All other subscriptions should be sent to Interscience Publishers, Inc., 250 Fifth Avenue, New York 1, New York.

MANUSCRIPTS should be submitted to the Editor, Charles M. Burrill, Radio Corporation of America, David Sarnoff Research Center, Princeton, New Jersey.

ABOUT THIS ISSUE

If our first article in this issue were not written by an experienced and successful research administrator, its title would seem presumptuous indeed. However, we think our readers will realize that Dr. Schott is justified, kindly, and constructive in suggesting that research administrators sometimes yield to the temptation to substitute formalism for the more difficult personal approach to administrative problems. This paper of Dr. Schott's stimulated considerable comment when it was presented at the recent Fall Meeting of the Industrial Research Institute at Lake Placid. Stuart Schott received his Ph.D. in chemistry from the University of Cincinnati in 1936. Prior to joining National Distillers and Chemical Corporation as a research chemist in 1945 he was with the U.S. Public Health Service and was a major in the U.S. Army Sanitation Corps during the war. In 1949 he became Assistant Research Director for National Distillers and is now Vice President, Research.

At the Lake Placid Meeting of the Institute, one entire session was devoted to the subject, "Professional Unionism," and another to the subject, "The Effective Use of Personnel Audits." We have selected one paper from each of these sessions for inclusion in this issue of *Research Management;* we expect to include other papers from these sessions in subsequent issues.

The paper on professional unionism relates experiences at Western Electric Company; it is by T. E. Shea, Vice President, Engineering. Dr. Shea has been with Western Electric and other companies of the Bell System since receiving his S.M. from Massachusetts Institute of Technology in 1919. Beginning as a development engineer, he became a supervising engineer in 1925 and since 1939 has held various executive positions within the Bell System. He is the author of an outstanding engineering text and reference book, "Transmission Networks and Wave Filters." During the war he was Director of Research, Columbia University Division of War Research. He has received honorary doctor's degrees from

Columbia University and from Case Institute of Technology.

The paper from the session at Lake Placid on personnel audits is by Arthur L. Lyman, President of California Research Corporation, the research subsidiary of the Standard Oil Company of California. In it he discusses the values accruing to their research laboratories through participation in a formal professional-personnel audit system applied throughout the Standard of California organization. Mr. Lyman graduated from the University of California in 1923 and has been with Standard of California ever since. Beginning as a research chemist, in 1937 he was made Manager of the Richmond Laboratories and in 1944 Research Director. In 1946 he became Vice President and Director, California Research Corporation, in 1953 Executive Vice President, and in 1954, President.

Closely related in subject matter to the above-mentioned paper by A. L. Lyman and to papers in the Spring Issue of this year by I. Goldman and by Frank D. Leamer on professional job descriptions and classifications is our contributed paper in this issue by Gilbert Kelton on the evaluation of scientific personnel. We caution our readers not to conclude too quickly that Dr. Kelton's position is entirely negative, for he is not against evaluation of scientific personnel but only against incorrect or misinterpreted evaluation. Dr. Kelton is Executive Assistant to the Director of Philips Laboratories, a Division of North American Philips Company. He graduated from Fordham University in 1941 and received his Ed.D. degree from New York University in 1951. He has been a high school and college physics teacher and administrator, a research physicist at the National Bureau of Standards, and a research consultant and administrator with a number of government and industrial organizations before joining Philips. During the war he was a major in the Air Force.

After the lapse of several issues we are pleased to be able to bring our readers another case history of outstanding research work. This is a history of the development of the Burroughs

equipment for high-speed reading and sorting of bank checks by means of magnetic printed characters. The author is I. M. Sheaffer, Jr., Manager, Systems Engineering Department, Research and Development Division, Burroughs Corporation Research Center, Paoli, Pennsylvania. This paper was presented at the Buck Hill Falls Meeting of the Industrial Research Institute last Spring. The check sorter involved unique problems because of the need for standardizing the basic magnetic-character language without dictating the design of the equipment. To some, this situation will suggest some of the system development problems faced in the introduction of color-television broadcasting.

ARE RESEARCH ADMINISTRATORS GETTING LAZY*

STUART SCHOTT
Vice President, Research, U.S. Industrial Chemicals Company
Division of National Distillers and Chemical Corporation, Cincinnati, Ohio

Over the past few years a good portion of the thinking community has concerned itself with the nature, operation, and problems of the business organization. Singled out for special attention has been the administration of research, partly because of the uniqueness of its product, *i.e.*, new developments, partly because it has but recently come into its own, and partly because of public concern with technological progress in certain areas. In addition, the impact of research expansion in terms of dollars spent and number of people involved has done much to attract attention. This subject of research administration, as you know, is one of the cornerstones of the Industrial Research Institute.

We research administrators are subjected to a myriad of formulae on how to enhance creativity, how to hire technical personnel, how to organize research teams, how to establish conducive environments replete with salary programs, organization charts, and colorful, appealing titles. The deluge of articles, seminars, and speeches on various aspects of the management of research, however, seems to be concerned especially with the use of organization in the handling of a research program. The effectiveness of all this verbiage when applied to the basic measure of research—the

* Paper presented at the Fall Meeting of the Industrial Research Institute, Lake Placid, New York, October 12–14, 1959.

idea translated into new products or processes—appears somewhat questionable. Admittedly, our administration of research is far from perfect, but, at the risk of being provocative, I think that many of the faults in research are attributable to our laziness. I do not mean that we fail to put in the required hours or that we consciously avoid allotting the necessary time and thought to the solution of problems. What I do mean is that, in addition to the routine duties which are common to other departments, research administrators are faced with the task of handling wisely the extremely complex gambling nature of the research process. The measure of success in research is difficult to evaluate, so there is a tendency to allow as much as possible to proceed in an arbitrary manner. This may be the answer to why the administrators of our era are seeking more and more the support and security of organization. This is, in my opinion, the lazy way out. Worst of all, it would appear that this leads to the philosophy, "if a little organization is good, more is better." A concerted effort is required if we are to avoid going too far down the road of regimentation.

Perhaps at this point we should stop to consider with what groups we associate ourselves. Although, technically speaking, we are professionals, because of the administrative duties involved, we are usually classified as executives. The wealth of literature on the executive, what he does and how he does it, expresses a wide divergence of opinion on what constitutes a good executive. Speaking generally, however, a good research executive is one who handles a research program effectively, extracting maximum benefit over a period of time for the development of new products or processes. Thus, in order to qualify as research executives, we should possess all the general qualities normally desired in administrators, a good scientific background, the ability to inspire the respect of technical personnel, and in addition a gambling instinct. Of course, we should live and think research almost continuously.

We sometimes act as if we were content merely to accomplish the organization and regimentation of our professional workers. This is lazy and inefficient, since there is certainly more involved than achieving what appears to be a smooth work flow, more than rules and procedures. This difference is very important, since only a small part of the work flow may make the difference between the success or failure of a research program. It is the encouraging, the bringing to light, and the increasing of really useful effort with which we should be concerned. Research by organization alone is by rule rather than reason. Organization, of course, has a necessary place in certain of the more routine operations, but in research, if not applied in a judicious manner, it can easily and imperceptibly become the master, rather than the servant of all concerned.

Perhaps, in attempting to orient ourselves with respect to our purposes in and responsibilities toward the research organization, we might look backwards and examine the infancy of the research bodies we represent. When our research departments consisted of only a few men, we had a minimum of formal administrative procedures, and yet our organizations were probably as ideal as any that human beings can hope to fashion. Communication was perfect, because it was oral and continuous. Good ideas, subjected to constant high-level professional analysis and constructive criticism, were rapidly assayed, embellished. tried, improved, and evaluated and reevaluated continuously. New ideas or procedures could be checked without running afoul of red tape. Poorer suggestions, by the same process, were promptly investigated and, if found wanting, discarded.

Unfortunately, as a research unit grows in size, the ideal of constant, personal communication among members becomes more and more difficult. To take its place a series of administrative procedures develop. Concern with efficiency in its operations, both routine as well as nonroutine, increases in an exponential manner. Then comes the introduction of instruction booklets,

personnel programs, efficiency ratings, and other administrative rules, all in the name of increased efficiency. In the worship of efficiency do we forsake our vision and bow instead to the idol of smooth operation? If so, this would indicate a mental laziness on our part. The research administrator can now become less the director, less the scientist, and more the professional paper shuffler. The more the administrator allows himself to become involved in the mechanics of procedures at the expense of what should be his primary duties, then the lazier he is, and the less productive his department. To emphasize: the more rigid the system, the less vibrant the organization; the closer the adherence to the *status quo*, the easier is the job of the research administrator, the less awkward are the explanations to management, and the less creative the department.

The number of key people in a research organization is relatively small, and in spite of all the furor about inspiring the ordinary person, such an effort is unlikely to be very effective in producing ideas. Good ideas occur normally to the person who is gifted with intelligence, experience, knowledge, and the ability to observe. The number of years of experience or graduate degrees is not always an accurate guidepost. Creativity in scientists is more or less an innate quality. Thus, one of our important tasks is to remove impediments to the functioning of the idea man. The urge to know or to understand is a tremendous drive, so sometimes it's best to let him alone since he probably knows more about what he's doing than we. No formula or system, regardless of its complexity, can be an adequate substitute for personal judgment, because no mathematical evaluation can hope to develop or to treat fairly the diverse personalities that make up a research body, or inspire in a group that feeling of belonging to the scientific community and the laboratory which is so necessary to the attainment of maximum efficiency. One purpose of the research administrator—perhaps his primary duty—is to serve these personal functions that are beyond the capability of any formula.

Emphasis on a project which means growth for the company or is of interest to the scientific community generates enthusiasm. This proper placement of emphasis requires some thinking on the administrator's part, but it is well rewarded. All of us have seen the spontaneous generation of enthusiasm when interesting results begin to appear from the research work. The observation of what happens in the laboratory or pilot plant or the discovery of something new sometimes means more to the professional man than any title, salary program, or auxiliary benefit. I am not suggesting that the technical personnel can exist on interesting work alone. This is no more true than the old cliche about living on love. Other rewards also have meaning and must be used.

In many cases we have been too lazy to think out just what an industrial research idea should be. It is not merely a wish for something. It is more than a plan of action for achieving an end. It is not merely a statement of an industrial need but more nearly a means of supplying the need. Discovering such new fields to conquer represents one of our major jobs.

Among other things, we should not look to professionals to take over routine administrative duties. We all readily agree that the creative men are the mainstay of the research group and point with pride to the intricate equipment and to the extensive and costly supporting services that we provide in order to free him from routine chores. We remind him that research administration and services exist for the sole purpose of making his job as productive as possible. Then we seem to reverse our attitude completely by trying to change a good professional into an administrator, sometimes a very poor one, merely to justify his earned increase in pay. We are lazy if we cannot justify his advancement in his chosen field. I'm happy to say that in some companies the tide seems slowly to be turning away from the lazy way.

A critical problem for the research director is searching out the right approach when his key people disagree on procedure. At times the laboratory is a veritable tower of Babel. Naturally,

a certain amount of disagreement is to be expected in any research laboratory where there are intelligent and enthusiastic professional personnel; however, there is a point beyond which disagreements should not be allowed to continue without some positive action on our part. Otherwise, time may be spent on proving solutions erroneous rather than in working out the optimum procedure. If we merely sit back and make an arbitrary decision in such matters on the basis of our own limited knowledge and preconceived ideas, weighted perhaps by the relative effect of the decision on the individual personalities involved, or if we salve our consciences by appointing an intermediary whose job it is to assimilate the proposals or ideas and present a digested opinion for our final evaluation, we are lazy. If we tend to suppress opinions along preconceived lines without getting to the root of the matter and obtaining a full, impartial understanding of the situation, we are lazy.

An alternative that I consider to be the most propitious, although the most nerve-racking, is to sit down with the scientists and listen to argument and rebuttal, allow them to hear and assimilate each other's views, and encourage the interplay of ideas and the critical examination by fellow professionals. Of course, we must guide the discussion carefully to ensure that the principals remain aware of the organization's primary responsibilities.

True, this is a difficult and wearing task. It requires the acme of diplomacy, the expenditure of considerable time, and the effort of technical preparation. But the results are their own reward; our men feel that they have contributed to a decision that affects their future. We may leave the discussion exhausted, but we shall be knowledgeable in the subject. The scientists have picked up new food for speculation. Some of that sought-after, throbbing life has returned to the organization, and, with a little luck the group has arrived at its own amiable solution necessitating only our implementation. At worst, we are still forced to make a decision, but we have the knowledge to make it intelligently and

in a manner that should be most acceptable to all the parties involved. As a result, we have played the role of a leader and are worthy of the title.

This technique has been applied also to professionals on different levels who have varying opinions. We must be aware of the fact that the scientist is not a paragon of virtue or modesty and does not always interpret facts in a completely impartial way. There are often differences of opinion between a supervisor and his subordinate on technical matters. If the supervisor is less than godlike, he may tend to suppress the opinion of the subordinate in the same way that he will argue against an equal. Unless we are lazy, we shall consider it essential in these cases to have access to the ideas of everyone with useful knowledge on the particular subject. This knowledge may be gained much better through conversations with the individuals than in a meeting of all concerned. Some professionals do not relish arguing with their superiors in a meeting. It is up to us as research administrators to know the various opinions and to act accordingly. It is amazing how much more quickly events move with this approach. It is also extremely heartening to the people involved to know that all opinions have been heard and that they have not been suppressed by whimsy or arbitrary decree.

Cutting across organization lines may be of extreme benefit if done with discretion. If we obtain our information solely by the organized method, *i.e.,* by either formal, written reports or oral reports from our next in line, we sometimes miss things we can obtain by the other approach, *i.e.,* walking around the laboratory or pilot plant and talking to the people working at the bench. There is much more involved here than just playing the interested boss. There is an amazing number of pertinent facts available from the bench worker which may provide us with a better view of what is going on in our domain. This information allows us to act much more intelligently than if we confined our actions to the commonly accepted and easier method of proceeding strictly

through the chain of command. We get all the advantages just mentioned, *i.e.*, the thinking of the men closer to the problem, be it only the mechanical end, also, these men have had personal contact with the boss. We stir up things, usually in a desirable manner, and sometimes, as a result, we may be able to contribute a worthwhile suggestion or idea (of course, through proper channels). This technique has been used to very good effect in research divisions on the nonprofessional as well as the professional personnel.

The ideal research director picks his personnel because of their technical and creative ability and not because they conform to a predetermined personality mold or have managed to pass a personnel evaluation test. Indeed, if we are really willing to exert ourselves, we will purposely attempt to select a variety of enthusiastic individuals. This will often necessitate that the organization conform to our choices. We must recognize that the interaction of diverse personalities upon each other enhances true creativity. Calm and smooth functioning is not necessarily synonymous with efficiency. Internally, we should encourage the bull-session and the research seminar, but always with some thought as to the primary purpose of the laboratories and not as a disguised sop to the intellectual mind.

In passing, the functions of the committee might be worth mentioning. Many times such a group is used in research for making decisions. This is wrong. The major purpose of a committee is to make certain that everyone present is acquainted with the others present and, it is hoped, with their views on the subject at hand. But we should not expect a committee to make any decisions for us, since by so doing we should be avoiding one of the essential duties of a research administrator.

Lastly, one thing is certain—the research organization is simply a mirror of its administrator. The lazier we tend to be, the less authority we delegate intelligently, the more we seek smooth functioning and individual conformity, the more we depend upon

formal procedures, the more we can expect only lower production, less creativity, and more mediocre results.

The greatest compliment that we can receive from a visitor to our installation is the statement that he is impressed by the enthusiasm and vitality of our staff. As long as our research divisions maintain a vibrant life, I am certain that useful results per unit expenditure will continue at a high level. I'm sure that all of us have our own particular means of accomplishing this end result.

To sum up, it seems we should value our personnel more for technical proficiency, spend more time on informal discussions with personnel at various levels, use organization instead of having it use us, and make certain we have a variety of professionals to keep things interesting. In trying to look inwardly we might recall the old Chinese proverb which says, "the man who is stupid and lazy can't get very far, but he can't cause much trouble. The man who is stupid and industrious can make a mess of trouble." The man who is industrious and intelligent is the best staff man. And the top man? Intelligent and lazy. So maybe we all fit the bill!

THE IMPLICATIONS OF ENGINEERING UNIONISM—WESTERN ELECTRIC EXPERIENCE*

T. E. SHEA

Vice President, Engineering, Western Electric Company, New York, New York

The beginnings of engineering unionism in Western Electric Co. were at one of our eastern plants in 1944–45. It is difficult to recount in a few sentences the history and the motivating factors. Four engineering groups came into existence seeking to be essentially informal "sounding board" groups; these later coalesced into one group. The reasons that led to their formation appear to have included: the effects of layoff and other retrenchment policies during the depression, when the Company's sales dropped from a 1929 total of $411 million to a depression low of $70 million, and, of course, the deep psychological reactions that flowed from that economic period; lack of sympathetic rapport between engineers and the local upper management of that period; the salary squeeze in which skilled people were caught as a result of governmental policies which gave relatively more to the unskilled and semiskilled; and various items concerning status and working conditions. In particular, the success of unions in securing increased wages during the war and immediate post-war periods was a significant factor.

* Presented at the Fall Meeting of the Industrial Research Institute, Lake Placid, New York, October 12–14, 1959.

It appears that initially the intent of the informal group was to establish constructive, harmonious relations with the Company. The Company refused to deal with the informal group, being limited by the Wagner Act in what it could say to employees (it might have been accused of domination of the group), and it was felt that in the existing labor climate the group would become a union. The group applied to the National Labor Relations Board (NLRB) for certification as a union and won the subsequent election. After certification, it attempted to operate informally without a contract, but soon recognized that as a union it must bargain through the medium of a contract.

There were many in management who supposed that, since engineers are reasonable people, the engineering union would continue to be a reasonable, constructive one. However, bargaining led to controversies, and these led to the taking of emotional positions. Then as the Union leadership changed and new ambitions influenced the attitudes of its leaders, strong antimanagement attitudes developed progressively.

In 1952 the Union sought and obtained Company-wide representation of our engineers. It did not win this by a large margin, as it had won the earlier election. In my opinion, in this case the Company failed to use vigorously its rights of free speech under the Taft-Hartley Act.

Although the Union was certified as a mixed professional and technical unit, it immediately moved to claim that it was essentially a professional union. It sought to limit assignments by the Company to jobs within the unit to people who in the union's opinion were professionals. When the Company refused thus to limit assignments, the Union falsely accused the Company of diluting the unit contrary to the certification.

During the period from June 1952 to November 1955, three one-year contracts were negotiated with the Union, in each case with a good deal of acrimony on the part of the Union over fundamental issues and with vitriolic material appearing in union

publications. A principal issue was that of minimum qualifications for professional people. The Union sought to define these qualifications in terms of academic degrees, or alternatively in terms of a rigid schedule of years of experience in lieu of degrees. The Company has maintained that, by law and in practice, although education is important, classification as a professional must be on the basis of whether professional work is actually done and whether it is satisfactorily accomplished. This recognizes that people vary in the speed with which they attain professional capacities. It means also that in specific cases the Company must be the judge of whether individuals do satisfactorily perform professional work; the latter point is one which is troublesome to the Union.

The Union attempted without success to gain by arbitration what it could not gain in bargaining. It also filed a civil suit for damages, which it later withdrew. It filed an unfair labor practice charge, which was dismissed. Finally, it called walkouts not legally sanctioned and engaged in some picketing. The Company disciplined those who engaged in and those who inspired the walkouts. As a result the Union filed another unfair labor practice charge; this was dismissed by NLRB.

From November 1955 to May 1957, no contract existed between the Company and the Union because of failure of the parties to agree. No contract has existed during the subsequent period to date.

In 1957 the Union requested the NLRB to conduct an election to determine whether the professional engineers wished to be represented by a purely professional unit. The Company welcomed this action as one giving the engineers another opportunity to decide whether they wished to be represented by a union. The Union relinquished its representation rights with respect to its mixed unit by the action of filing with NLRB for an exclusively professional unit, and the Company has not bargained with the Union since that time.

The NLRB hearings on determining the eligibility of individuals to be included in the proposed new unit have been long and protracted. The reasons for this have been well covered by the company in a pamphlet entitled "Why Western Electric Opposes the CWEPE-N Union." The record of the hearings is now under scrutiny by NLRB, and an election is expected to be ordered shortly.

The Company has done many things to improve its engineering personnel situations, particularly during the past five years. Many of these things are detailed in a booklet entitled "Insuring Optimum Use of Engineering Abilities." These things have not been done at the urging of the Union, but because the maintenance of an effective, creative engineering force is indispensable to the Company's objectives. In many cases the Union, when it had representation, acted as a delaying factor.

Whether or not we shall have a union in the future, we are dedicated to the policy that evolution and improvement must continue to take place with respect to salary practices, reduction of nonprofessional work, opportunities for recognition, rotation, and training, progress by engineers without necessarily going into administration, and the like. There is, in particular, need for improved communications so that the views of individual engineers may be better known to management, and, therefore, understood and more sympathetically considered. It is essential here to recognize that engineers have a dual loyalty to their employers and to their profession. These need not be incompatible, but the needs of each must be satisfied.

As we look back on our experience with the engineering union, our position is as follows. Engineering unionism and true professionalism are incompatible. Engineering unionism is detrimental to the interests both of the engineers and of the Company. These conclusions were reached on the basis of several factors: first, the course of evolution of the union's character, as epitomized by the history of the CWEPE-N Union; and second, consideration of

the intimate and damaging effects which divisive tactics have on the teamwork which is particularly vital to engineering work and on the performance of individuals.

No matter what the motives of engineering union leaders may be initially, as controversies arise in bargaining they are likely to be led into personal attacks on supervision. The union leaders defend themselves by asserting that supervision is blind, lacking in foresight, ill-willed, or conspiratorial. These adjectives are indicative of the character of many assertions that have been made. The effect (and I believe an intended one) is to sow doubt and distrust, to get people to believe that the Company is reluctant to make improvements and will do so only as a result of militant action. In our case, it has been asserted repeatedly that the Company conspires with other companies to restrict salary levels; that the Company exerts undue influence on Government; that the Company makes money at the expense of engineers; that first-line supervisors are incompetent, antipathetic, or forced to act against their desires by upper management; etc. Union publications attacking the Company have been widely circulated at engineering schools. Social and work pressures have been brought to bear on nonmember engineers, and cooperation on their work threatened or withheld. Strikes and picketing have been engaged in by the CWEPE-N Union (part-time walkouts in this case) and by other unions as well.

The course of evolution tends to lead these unions to become affiliated with national union organizations of either the trade union or the technical kind. The objectives of engineering unions are affected by these affiliations. The engineering union of which I write is affiliated with the Engineers and Scientists of America (ESA). There is no doubt that a broad objective of ESA is not merely the organizing of all engineers and scientists but, going beyond this, the attainment of a nationwide professional closed shop in which an engineer or scientist would have to meet professional standards established by the union in order to make

a living. Moreover, representatives of the CWEPE-N Union have attended labor-union meetings, have been silent when professional attitudes were attacked in such meetings, and have published articles reflecting militant trade-union views. It is, therefore, important to look beyond today's difficulties and see where such movement may go if allowed to do so.

Teamwork is vital to professional and managerial people. I know of no first-rate institution whose professional and managerial personnel do not believe enthusiastically in that institution, do not have trust in one another's integrity and competence, and do not achieve through teamwork what as individuals they could never achieve.

Now comes a class of organizations who attack that teamwork by attacking the integrity and competence of the institution and its management. Those of us who have spent time in the labor-relations field have become used to what the lawyers call in trade-union bargaining "the allowable exaggerations of bargaining." We are forced to accept this as a tactic, even when in the extreme it involves misstatements or fabrications made as a means to an end. But trade unions do not represent, for the most part, people whose productivity and creativity depend so heavily on their mental and emotional states, people whose minds and emotions need to be concentrated on the professional task at hand. Here lies the paradox of professionalism and engineering unionism. One cannot expect the best results from a professional group if they become embittered against those for whom they work. This, of course, is a part of the reason for the ethical necessity for decency in relations with employer or client.

Managing an industrial company is an extraordinarily difficult task. Executives would be helpless to perform their functions without facts and recommendations furnished by large numbers of management people or the insights and alertness that arise from the devotion of these people to the business. Moreover, engineers

in their work depend on teamwork with accounting, operating, personnel, and other management people.

Professional engineering in industry resides in bringing technologies to bear, in all possible ways, on the conduct and improvement of the business. Thus, engineers are clearly part of management. Their decisions and recommendations affect the spending of large amounts of capital money, the efficiency and flexibility with which facilities may be used, the form and amounts of large inventories, the processes used in making things, and the quality and economy with which these are made. Engineers help shape the future of a business.

There is no more basic test that may be applied to an industrial company than the quality of the teamwork among its executives, engineers, and other management personnel. The effort of an engineering union to sow doubt and distrust therefore may not be dismissed as a bargaining tactic. Such an effort strikes at the vitality of the enterprise, and probably has an equally important effect on the productivity of the individual engineer.

I do not propose here to predict the outcome of the impending Western Electric election. We have taken many steps, formally and informally, to express our views on this matter to engineers. On the one hand, we are dealing here with intangibles which, vital as I believe them to be, require reiteration in order to be understood. We are also dealing, to a considerable extent, with future effects whose full significance comes only with experience. On the other hand, it is easy for an engineering union to demand numerous things, to attempt to take credit for what is done, to say that it was done reluctantly, and to claim that if the union ceases to be around improvements may not continue, even when the engineering union has been itself a retarding factor in the making of improvements.

I am hopeful that the engineering union will be defeated but, to accomplish this, it will be necessary for the great majority of engineers to take the trouble to vote. This we are encouraging them

to do. If, despite this, the union should win, the fundamental issues will not be altered. We will continue to manage our business. We will continue to improve our engineering personnel practices in ways that we consider to be sound. And we will fight, in every way possible, the baneful effects of the union on teamwork.

In conclusion, I should like to list sixteen objectives which we have set for ourselves in order to maximize engineering effectiveness and personal satisfactions.

1. To provide adequate salary compensation, tested by what is necessary to maintain a high-caliber staff and to reward productivity and creativity, and tested by the practice of other progressive companies.
2. To provide an adequate professional future for engineering leaders within engineering.
3. To organize engineering groups in the company in a manner consistent with this goal, and to place engineering specialists in positions where their contributions may be maximized.
4. To maintain professional quality of staff through critical examination of recruiting and hiring, weeding out, personal appraisals, individual development, and stimulation from inside and outside influences.
5. To maintain friendly, informal working relations with individual engineers, to engage in candid personal-appraisal discussions with them, and to maintain effective communication channels upward and downward.
6. To maintain engineering personnel groups through which engineers may freely submit problems or questions, with assurance of thoughtful consideration and confidential treatment.
7. To maintain an effective program for rotation and experience, so as to broaden and deepen individuals.
8. To promote technical depth, especially in the newer fields.

9. To encourage suggestions, technical contributions, and publications, and to give concrete recognition for such contributions.
10. To minimize the doing of nonprofessional work by engineers, through the use of adequate support personnel, including clerks, technicians, and engineering associates.
11. To develop among engineers better understanding of the Company's economic problems.
12. To provide engineering facilities (office, laboratory, model shop, drafting) of such kinds and in such locations as to maximize speed and effectiveness of work.
13. To arrange delegations of authority to minimize delays and routines, consistent with reasonable controls.
14. To look for and develop engineering leadership.
15. To encourage boldness and chance-taking, consistent always with high standards of thoroughness and economic soundness.
16. To maintain the Company's technical competency and its reputation outwardly, through effective relations with competitors, suppliers, research institutes, universities, and engineering societies.

Obviously, these objectives require continued development to achieve fullness of accomplishment, and we will be working on them through the years ahead.

PERSONNEL AUDITS IMPROVE QUALITY OF RESEARCH PERSONNEL*

ARTHUR L. LYMAN

President, California Research Corporation, San Francisco, California

Introduction

We consider that an effective personnel appraisal program is an essential tool of research management. In the following, I shall try to illustrate how our appraisal program works and why we consider it effective.

It may be helpful to explain our company's organizational setup before proceeding. The Standard Oil Company of California is an independent, integrated oil company, and has no linkage with other Standard Oil companies of this country. In fact, we are in direct competition with the other Standard Oil companies, as well as with other petroleum companies such as Shell, Gulf, and Texaco. Standard of California has total annual sales in the western hemisphere of approximately 1.6 billion dollars. Domestic operations are carried out by a number of wholly-owned petroleum and petrochemical companies, including Standard of California Western Operations, Inc., The California Company, The California Oil Company, California Spray-Chemical Corporation, and Oro-

* Presented at the Fall Meeting of the Industrial Research Institute, Lake Placid, New York, October 12–14, 1959.

nite Chemical Company. In addition, our company has major wholly-owned operations in other parts of the western hemisphere and is a major partner in the operations of the Arabian American Oil Company and the California Texas Company which operate in the eastern hemisphere.

California Research Corporation is the wholly-owned research organization for Standard Oil Company of California; as such, we carry on the research, development and technical-service activities for the parent organization. In addition, we are its patent-holding and licensing agency. We have over 1400 employees; of these, nearly 700 are professional people with college degrees in a wide variety of disciplines. We have four locations, our largest laboratory at Richmond, California, employing about 1000 employees. Two laboratories are located in the Los Angeles area, one with 275 employees and the other with 50. Our home office has about 120 employees, including our Patent Department.

Appraisal and Development Program

Extensive use of personnel-appraisal procedures was started in Standard of California in the early 1920's, and the present company-wide appraisal and development program was derived from the experience and observations of supervisors throughout the company. A guide for supervisors was published in 1952. The following quotations from the introduction to this guide state very well the reasons for our appraisal program.

> "Appraisal of employee performance and well-planned counseling to assist the employee in his development are among the best practices of every good supervisor.
>
> "The good supervisor applies training and development daily in his relationship with his employees on the job. However, much is gained by making a thorough and systematic appraisal and putting it down on paper at periodic intervals, followed by a planned discussion with the employee at a time that is appropriate.
>
> "Employees throughout the Company have responded favorably to ap-

praisals of their performance, made in thorough fairness and with sincere interest in their progress and development."

One important feature of our plan is that the stated primary purpose is to aid the employee in his growth and development by appraising all phases of his performance and then by following through with constructive discussion and guidance. When this is executed thoughtfully and skillfully, we feel that the plan accomplishes several additional important purposes. These include the following.

1. Promoting the employee's job satisfaction and morale by letting him know that his supervisor is interested in his progress and development.
2. Serving as a systematic guide to the supervisor in planning the employee's further training.
3. Assuring the considered opinion of the employee's performance rather than snap judgment.
4. Assisting in planning personnel moves and placements that will best utilize each employee's capabilities.
5. Assisting in locating and recording special talents and capabilities that might otherwise not be noticed or recognized.
6. Providing the employee an opportunity to talk to his supervisor about job problems, interest, future, etc.

We follow the overall Standard Oil plan. However, the specific details which I describe here apply to Cal Research. Our procedure involves rating the performance of new employees at least twice a year during the first year and annually thereafter. These ratings are an appraisal of each employee's current performance in his present assignment compared with that of others at the same salary level.

Consideration is given to a list of characteristics, including knowledge of work, planning and organizing ability, analytical ability, judgment, initiative, etc. In reviewing each of these

characteristics, our appraisal sheet provides space for remarks. In this space we expect the supervisors to record pertinent information which will enable other members of management to review the rating intelligently and will also serve as a guide to the supervisor in later discussion with the employee. After the rating is completed on the more detailed characteristics, a summary rating describing the employee's overall performance as "Unsatisfactory," "Fair," "Good," "Very Good," or "Excellent" is designated by the supervisor. This summary rating does not represent an average of the appraisal on individual characteristics, as we have not assigned values to these various items. On the other hand, it is a judgment rating by the supervisor. Here again, space is provided for explanatory remarks, and we place a good deal of emphasis on these being properly recorded for the reasons indicated above.

Our form also has a supplement which provides for consideration by the supervisor of the individual's outstanding qualifications and abilities, as well as those of his characteristics which require improvement or strengthening. This supplement is particularly useful in reviewing the employee's potential for higher assignments, either in the same line of work or in other fields.

In making these ratings, we use the conference method. In addition to the immediate supervisor and at least one other supervisor having knowledge of the employee's performance, a personnel representative takes part in the review. He contributes to a broader understanding and overall correlation of the appraisal system and also serves as a check on the consistency of application of our principles in the appraisal system, supplementing the more intensive or detailed knowledge about the employee's performance which the supervisors have. Final responsibility for the accuracy of the appraisal and the discussion with the employee rests with the employee's immediate supervisor.

In the discussion of the appraisal with the employee, we emphasize the "development feature" of our plan. The supervisor points out as objectively as possible both the strong points and

weaknesses of the employee and encourages him to participate in the discussion of the various factors. While we do not require that the form be shown to the individual, this will be done if he requests it; in many cases, the supervisor prefers to handle the discussion in this manner. I believe you will recognize in this feature a built-in check on the type of statements that supervisors will enter on the rating form. It has been our experience that this avoids extreme emphasis on either the favorable or unfavorable comments.

Following the discussion, the supervisor records the results of the interview, briefly telling what suggestions were made and what agreement was reached on plans for the future. In some cases, the record shows an area of disagreement.

As an additional check on the over-all effectiveness of our rating procedure, all ratings of our professional personnel are reviewed by the Manager of Organization and Cost Control and the Business Manager, who are members of the President's staff.

Reports and Overall Performance Summary

The management of each laboratory is responsible that ratings are made in accordance with the policy and that the discussion with the employee is carried out and properly recorded. As an additional check on the overall effectiveness of our appraisal system, since 1947 we have made an annual review to determine the least productive 5% of our people in each laboratory. In addition, more recently we have made a similar review of the 5% who are believed to be the most productive. These reviews are carried out by managerial divisions (from 50 to 150 professional people) on the basis of a forced-choice procedure. The managers select the highest and lowest 15% of the employees, based on effectiveness in their present assignments. Members of the President's staff and laboratory management then meet to review these 15% lists and reduce them to a 5% low and high at each location. In the case of

the low 5%, a brief description of each man's problem is prepared, and the laboratory's plan for solving it is stated. These 5% lists are then summarized by the San Francisco staff for all of Cal Research, and the summary is discussed with the President. The Business Manager has been assigned the responsibility for appropriate follow-up to insure effective action before the next review period. The need for this follow-up varies considerably in each individual case.

The list for any given year is not considered absolute. Every effort is made to see that it is as accurate as possible, but we recognize that errors will be made. The list serves the following purposes.

1. It highlights the newly-hired employee who is not suited to work assigned him. We are able now to identify this problem more readily since we have been carrying out the low 5% review for 12 years. Depending upon circumstances, we consider change in job placement; we counsel with the employee as part of the regular appraisal program; and, when appropriate, we terminate or encourage resignation.
2. The least productive employees (even though they may be making a reasonable contribution) are highlighted for management's attention once each year. Deadwood accumulates in most organizations because its growth is undetected. We feel that these lists are a powerful deterrent.
3. When conditions change suddenly, arbitrary decisions on termination or transfer can be avoided. Surprise by the individual concerned at the action taken can be avoided.

In a research organization, optimum use of the top 5% of the professional group is of utmost importance to the organization's research program. Our review of this list helps to ensure that these people are receiving adequate recognition and that we are utilizing their high potential. Every effort is made to see that their

assignments are sufficiently challenging to develop them as rapidly as possible. Formalized procedures for ensuring the proper handling of this group are less necessary than for the low performers.

On the other hand, with respect to the least effective group, a concerted effort is made to ensure that each employee knows what management considers his problem to be and that improvement is expected. We do not consider this list to be a termination checklist, and it should be stressed that we do not weed out 5%. However, many problem cases are found through these reviews, and a start is made toward their solution.

Employees' Reaction

In recent opinion polls in our company, the employees have endorsed our appraisal program. Most of them welcome the opportunity to discuss their performance with their supervisor. When we tell new employees about our plan, they are pleased to know that they will be informed of their progress or lack of it. Another reaction which may be surprising to many people is that the employees as a whole appreciate the management action of weeding out the least effective group. We believe this opinion is re-enforced when it is demonstrable that the approach is one of constructive development.

Management Reaction

From the point of view of management, these systematic, periodic appraisals and discussions provide an opportunity to consider each individual employee. It has been our experience that even our best supervisors are often reluctant to discuss the individual employee's problems with him. I believe this is particularly true among the professional people. It is much easier for them to work on the improvement and utilization of their better people. Having a systematic plan with some built-in audit fea-

tures that require accountability on the part of supervisors assures more appropriate action. After the supervisor develops the technique of discussion and sees the positive results that occur after this frank approach to the problems, he is usually completely sold that this is a method by which he can measurably strengthen the performance of his entire group. Another benefit from the supervisor's standpoint is that if these appraisals are performed correctly, they eliminate that distressing comment, "Nobody ever told me I wasn't doing well." The additional review of the individual ratings by members of the President's staff is also recognized by our supervisors as an aid to them rather than just a check on them, as experience has shown that, in reviewing the appraisals, the President's staff are frequently able to suggest solutions which may not have been considered possible by local line management.

Another benefit accruing to top management from the appraisal system is that the review of individual appraisals also gives an insight into the supervisors' effectiveness.

No matter how good a program may look on paper, the ultimate criterion is how it works. Tables I and II give an indication of what we have been able to do using the low 5% audit procedure. The 30% shown in Table II to be potential problems represent 26 individuals; of these, only 14 appeared on last year's 5% list. The other 12 individuals have consistently appeared in the 15% list, and as borderline performers are also potential long-term problems. We know that as operating conditions change and as other, less productive performers are weeded out, these people may drop back again from time to time to the 5% list. One benefit of these continuing reviews, however, is that both we and the employee concerned have been forewarned.

Conclusion

Our overall appraisal program has maintained a good minimum level of performance and has improved the average level of

professional work. The appraisal and development program is effective because it is well known and accepted by our technical employees. The 15% and 5% review lists are a management tool only. They provide a forced-choice method of ensuring adequate review.

We believe the success of our program is in large measure due to features which create a "built-in" accountability by the line supervisor.

1. He has to certify each year that all employees have been appraised in accordance with policy.

2. His ratings and remarks on each appraisal form are subject to check by the other members of the rating conference, by the employee, and by the President's staff.

3. He must record his views concerning future development of each employee.

4. Forced choice of 5% lists compares quality of his people with those of other supervisors.

Other features of our program which tend to insure its effectiveness are the following.

1. It affords earlier recognition of the need for additional training of supervisors in personnel matters.

2. Meetings between the President's staff and laboratory management in the 5% review provide a common basis for understanding the goals of the program and the problems discussed. As a result, constructive action is normally possible.

3. It is a total audit of quality—not just selected groups or individuals.

4. Top management's willingness to take constructive action is apparent to all supervisors and encourages them to initiate similar action for other cases.

We consider that personnel audits of the type described here are definitely a factor in contributing to high morale and high productivity of a research organization.

TABLE I

Low-Performance Lists: 1954–58 (Inclusive)

Number of times listed	Number of names
1	59
2	14
3	9
4	4
5	1
Total[a]	87

[a] Although 135 entries are on these five lists, only 87 individuals are involved because some were listed more than once.

TABLE II

Summary of Five-Year Experience with Low-Performance Personnel

	Per cent of total[a]
Solved	63
Improved performance	14
Retired or transferred	5
Returned to college	6
Resigned or terminated	38
Current cases	37
Near retirement	3
Under active consideration	4
Potential problems	30
Total	100

[a] Total of 87 individual problem cases reviewed.

HIGH-SPEED DOCUMENT SORTER: A CASE HISTORY OF A NEW-PRODUCT DEVELOPMENT*

I. M. SHEAFFER, JR.

Manager, Systems Engineering Department, Research and Development Division,
Burroughs Corporation Research Center, Paoli, Pennsylvania

The story of the Burroughs High-Speed Document Sorter-Reader is one of a competitive product development which was influenced by customer demands and an industry-wide standardization program. It is a case history of research in action in the field of commercial data-processing equipment.

The Burroughs Sorter-Reader is a recently developed product which automatically reads and sorts magnetic-character bank documents at high speeds. It was developed as an answer to the ever-increasing problem of accurate and rapid processing of the large volume of paper checks and other unit documents that flow through the nation's banks.

To give some measure of the scope of this paper work problem, I would like to repeat some of the estimates that have been published in trade journals in recent years. It has been estimated that, in the last 20 years, the volume of checks which flows annually through the nation's banks has increased from approximately $3^1/_2$

* Presented at the Annual Spring Meeting of the Industrial Research Institute, Buck Hill Falls, Pennsylvania, May 4–6, 1959.

billion to approximately 12 billion. This increase in check volume is expected to continue until a total of at least 22 billion items per year is reached by 1970. On the average, each of these checks is processed from five to ten times as it passes through several banks for collection.

By the early 1950's the banking industry and most of the major business-equipment manufacturers had recognized the need for processing paper checks automatically, and each of the manufacturers had begun developing prototype document-handling equipment. Although the specific approaches, with their advantages and disadvantages, varied between companies, all had the common ingredient of automatic machine reading of documents and automatic sorting and processing. In the case of the Burroughs Corporation, a method of coding checks with invisible fluorescent spots was chosen. This work was pursued by the Todd Co., which is now a member of the Graphic Systems Group of the Burroughs Corporation. The fluorescent coding program extended into basic studies of papers, methods of imprinting, and methods of sorting and reading and progressed to the status where the industry's first paper-check-sorting machine was developed and installed in several banks for field trials.

During the same period, the Bank Management Commission of the American Bankers Association (ABA) established a Committee on Mechanization of Check Handling to study and recommend techniques for bank automation. On April 5, 1954, a technical subcommittee was appointed to expand the study and to formulate an industry-wide recommendation for choice of a common machine language. In July of 1956 the subcommittee formally recommended the adoption of magnetic ink characters for the common machine language. This recommendation was based on the advantages of having a machine language easily readable by humans, on the relative insensitivity of the magnetic ink signals to mutilation by most over-stamping, endorsing, and normal mutilation, and on the feasibility of the approach, as

demonstrated by the Stanford Research Institute under sponsorship of the Bank of America. Despite the heavy investments in other approaches to bank automation, the major manufacturers of business equipment recognized the need for a truly common language and joined in adopting the recommendations of the ABA.

The decision to accept the common-language recommendations of the ABA carried with it a number of management problems. To the Burroughs Corporation it meant the complete recasting of research and development programs for bank automation, the revision of production schedules, the initiation of new studies of product concepts and systems economics, and the modification and rearrangement of organizational structures to meet the challenge of competitive pressures and tight time schedules. Externally, it meant providing a responsible approach with competent management and technical personnel to work cooperatively with competitors in establishing meaningful specifications and workable standards for the proposed common language.

The problems of establishing a workable common language were attacked by the formation of a number of technical committees and subcommittees by mutual consent of the various machine manufacturers and printing firms. An Office-Equipment-Manufacturers Committee, consisting of representatives of both equipment manufacturers and printers, was formed as an official contact with the ABA committee on matters of equipment manufacture and techniques. A Type Design Committee was formed to study the problems and tolerances involved in the printing of magnetic characters. A Type Font Committee was formed to study the character shapes and their relationships with reading-equipment reliability and printing tolerances. A Machine Manufacturers Committee was formed to appraise the overall engineering reliability of magnetic characters. Additional subcommittees were formed for conducting a field evaluation program and for standardizing magnetic inks and methods of measurement and inspection of printing.

The problems faced by these committees were varied and

involved the many detailed aspects of character shape, tolerance, format, and location on the documents. Committee action was made especially difficult because of the proprietary positions of the various committee members and their competitive equipment objectives. Because of these competitive interests, the goal of the committees was to achieve standardization of the basic machine language but *not* the standardization of reading and processing equipment.

As the committee work progressed, it became clear that some of the equipment manufacturers were planning to use different methods for reading the magnetic characters and that these methods imposed different requirements and constraints on character shapes and tolerances. In some cases, these differences were in direct conflict; in other cases, the different requirements were compatible or supplementary. Similar conflicts in requirements also existed from the point of view of the printers. Here the problem was one of defining a common language that could be printed on the wide variety of existing printing equipment, all of which had different capabilities as to printing quality and format and which represented substantial capital investments. Because of these problems and conflicts, the establishment of a common language required many compromises on the part of committee members and a fundamental willingness to give a little on competitive equipment advantages in the interest of industry-wide standardization.

Since July 1956, the various committees have held at least 30 official meetings in six different cities of the East, West, and Midwest. Approximately fourteen business concerns (not including banks) were represented at the meetings. In December of 1958, the committees succeeded in unanimously recommending a magnetic character common-language font known as E-13B. In cooperation with the ABA, the committees also succeeded in standardizing the location and format of the magnetic characters along the bottom edge of the checks. During the more than two years

of these committee operations, the courtesy, the responsible action and the constructive approaches that prevailed reflected great credit on the committee members and the firms they represented.

In the Burroughs Corporation, the activities of the technical committees were closely paralleled by extensive research and development investigations into the problems of paper-check handling, character recognition, systems studies, and designs. One of the early questions that had to be answered was whether the products developed under the fluorescent program should be modified for magnetic character recognition or whether completely new approaches should be taken. In the case of the paper-check sorter, the decision was made to develop a completely new machine. This decision was prompted by a number of reasons:

1. The change from fluorescent coding to magnetic character recognition had a significant effect on the economic aspects of the sorter.
2. Magnetic character recognition imposed a family of new technical requirements on the equipment components which could be more readily achieved in a new design.
3. Experience gained in field trials and the successful development of new techniques at the Burroughs Research Center indicated that substantial improvements in sorting speed, ability to handle greater degrees of document mutilation, and wider ranges of check sizes could be achieved with a new design.

As part of the decision to initiate the development of a completely new document sorter, the whole subject of organization and administration came up for review. Normally, the development of new-product prototypes at Burroughs is the function of the engineering organizations associated with the Manufacturing Product Line Division. In this case, the Plymouth Engineering and Manufacturing Division of the Burroughs Corporation was designated as the cognizant product line division. At the time the

document-sorter project was initiated, however, the Plymouth Division was heavily committed to other product programs, the permissible time schedule was extremely short, the product specifications required major advances in the state of the technical art, and the intimate knowledge of these advanced techniques was concentrated at the Burroughs Research Center at Paoli, Pa. In view of these factors and the desire to satisfy the competitive pressures for a document sorter without upsetting other high-priority product programs, a tailor-made organization which crossed a number of divisional lines was set up for the sorter project. Although unique to Burroughs commercial-product development, this organizational structure was quite similar to ones used in some of our military research and development programs.

With primary cognizance and responsibility for the Sorter program assigned to the Plymouth Division, the responsibilty for the development of the prototype sorter-reader was subcontracted to the Research and Development Division of the Burroughs Research Center. The development project team was organized in the Business Machines Department and was under the direction of Mr. Walter Hanstein as Project Manager. (Mr. Hanstein is currently Manager of the Business Machines Department, having been appointed to this position on February 11, 1959.) In addition to Research Center personnel, the project team included personnel from Plymouth Engineering and Manufacturing. Applicational guidance in the form of specifications and functional requirements was provided by the Future Products Division in Detroit. Detailed and ambitious schedules and budgets were prepared and top commercal priority was assigned to the sorter development project at the Research Center.

The objectives of the sorter-reader development project were to develop *in one year* a prototype unit meeting specifications which are summarized below.

1. Sorting

a. Speed: Automatic sorting at speeds up to 1500 docu-

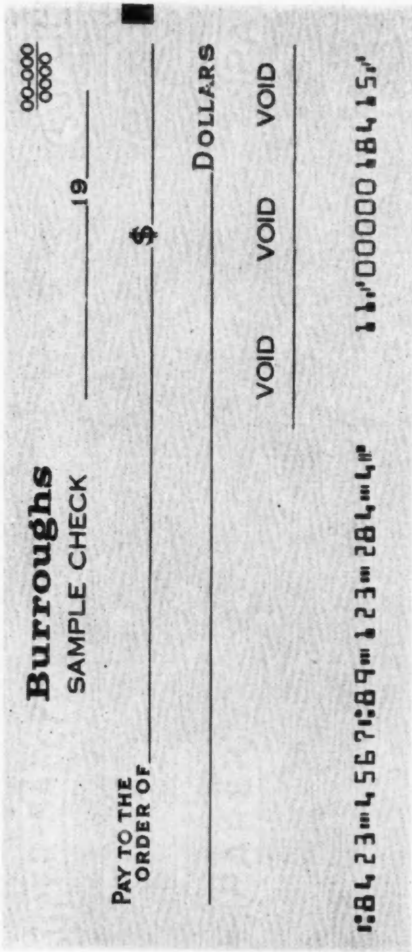

Fig. 1. A sample check showing the standardized location and format of the magnetic characters along the bottom edge.

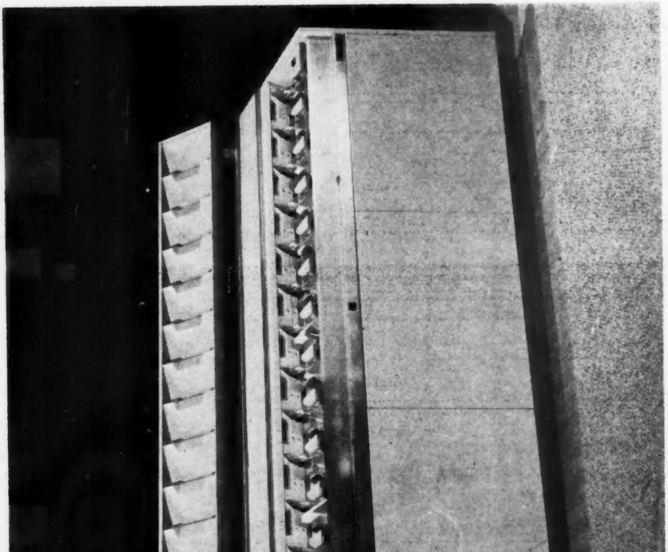

Fig. 2. The Burroughs High-Speed Document Sorter-Reader.

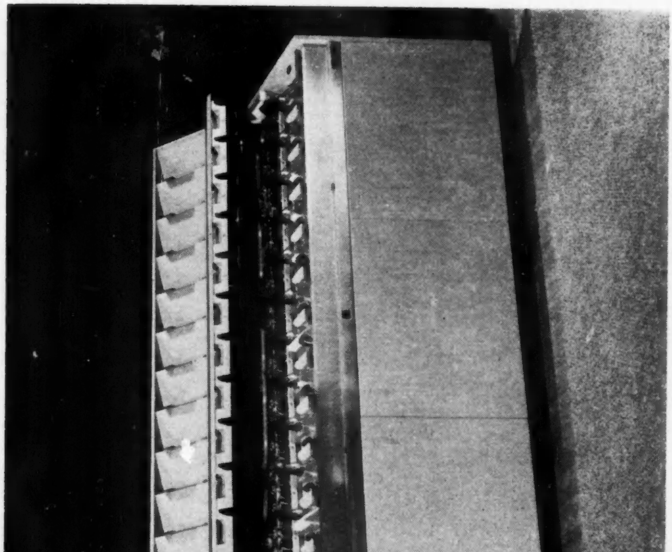

Fig. 3. Access to the complete check path of the Burroughs Sorter-Reader is obtained by raising two covers.

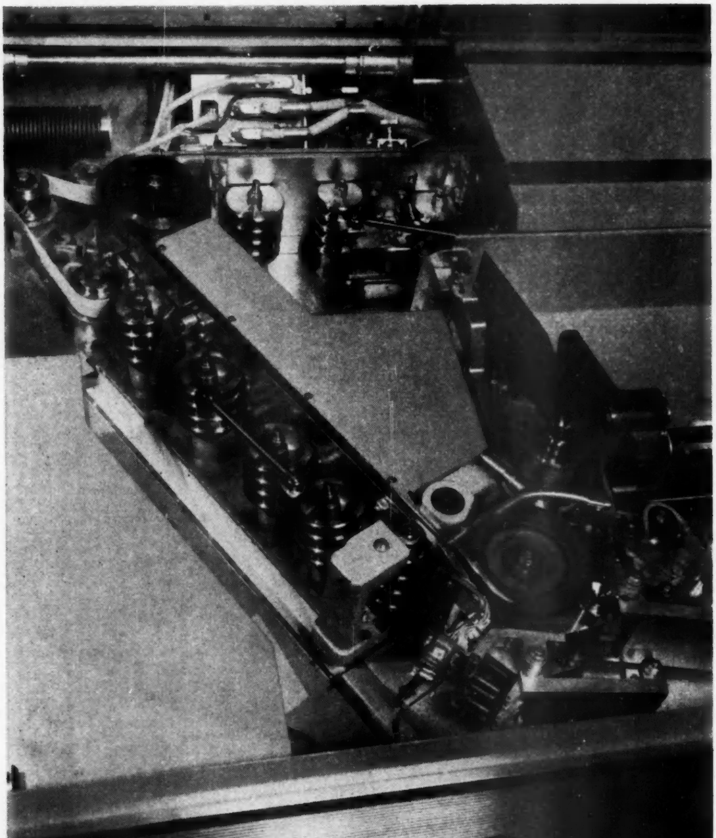

Fig. 4. Close-up view of the feeder, aligner, reading station, batch printer, and standby station.

ments per minute (25 per second), with emphasis on the full utilization of this speed by providing the ability to load and unload the machine continuously during sorting.

b. Documents: Ability to process intermixed paper and card documents of different sizes and varying degrees of mutilation, without prior jogging of documents or alignment to any reference edge.

c. Flexibility: Ability to sort on any character in the magnetic-character field as standardized by the ABA; ability to extract directly, simultaneously with normal digital sorting, special groups of items on the basis of multidigit numbers or special additional code digits; ability to check and assure proper field lengths, starting and stopping symbols, and reliable recognition of proper sort digit or digits.

d. Reliability, Safety, and Human Engineering: Provision of long-term, reliable operation under "worst-case" conditions of commercial environment, component tolerances, and check-printing tolerances; insurance of complete, convenient, and safe access to any part of the paper check path; insurance of fool-proof protection to the operator against exposure to physical injury from any high-speed mechanism; provision of convenient access to all functional components in order to achieve ease of maintenance and repair.

2. Reading: To be useable as an externally controlled document reader for reading of check information into other automatic data-processing, conversion, or computing equipment.

   a. Speed: Any document rate up to 200 documents per minute on a one-at-a-time demand basis.

   b. Documents: Same as for sorting.

   c. Flexibility: Ability to control all functions of the sorter-

reader from remotely located external equipment; ability to stop and hold an item after it has been read until the external equipment decides the appropriate pocket destination; ability to imprint on the item an identifying number to permit reconstruction of the original grouping of the items if required for accounting proof operations.

The project work at the Burroughs Corporation Research Center was organized into subprojects, representative of the various research and development tasks, which included logical design, document-handling mechanisms, character-recognition equipment, counting and control circuitry, power supplies, physical arrangement, and styling. By far the greatest amount of effort on the project was devoted to the research and development of the document-handling mechanisms. Although the processing and controlling of pieces of paper might seem to be a very simple problem, it is, in fact, very difficult. This is especially true in the case of bank documents, since the documents are not subject to the control of the engineers but already exist in a wide variety of sizes, types, and weights of paper. In addition to the lack of scientific control that might have resulted in "engineered documents," the engineers also had no control of the way in which the documents are handled between the time they are printed and the time they reach the banks for collection. This meant that the document handling mechanisms must be able to process the documents even after they have been folded in wallets, stapled to letters, torn with rubber bands, etc.

As a result of these basic difficulties, even the most simple functions of the document-handling mechanisms became significant problems and required appreciable research and design effort for solution. In the Burroughs Sorter-Reader, the document-handling problems were classified and treated separately in the following categories.

1. Feeding: The picking of one document at a time in cor-

rect order from a stack of intermixed documents.

2. *Separating:* The separation of several documents which might have been fed together.
3. *Turn-around:* The changing of direction of motion of the document.
4. *Alignment:* The registration of a document to a reference edge while it is moving toward the reading station.
5. *Reading station:* The control of document speed, registration and surface position as it passes over the magnetic reading head.
6. *Stop station:* The stopping and registration of documents travelling at high speed.
7. *Pocket (chute) selection:* The routing of the document to one of thirteen pockets.
8. *Transport:* The delivery of a document from one position to another in a linear direction.
9. *Stacking:* The placement of documents in a pocket in correct order and in proper registration.

Design of the document handling mechanisms involved mechanical engineers, electrical engineers, chemists, components engineers, fabrication specialists, mathematicians, and the services of engineering organizations of a number of component suppliers. Although the document-handling work required a high degree of technical competence and creativity in each of the appropriate fields, much of the design work was empirical. Development of most of the designs was a matter of trial and error and involved extensive testing of each design change. Components were tested with the use of standard groups of intermixed mutilated checks which were assembled on the basis of field statistics. High-speed photography was used extensively in evaluating the document-handling component designs. Because of the high-speed operation of all the mechanisms, high-speed photography was especially valuable in permitting the engineers to see exactly how the components were performing.

In addition to the design and study of mechanisms, the document-handling workalso involved studies of materials. Properties such as friction, hardness, wear resistance, and abrasiveness were important to the proper and nondestructive handling of paper. Extensive work was done on materials for the feeder and separator belts and rollers, the document turn-arounds, the reading-drum surface, and the snubbing rollers for the pockets.

Another area of particular interest in the development of the sorter-reader was the character recognition. Here again, the "real-world" requirements made a relatively simple job complex. The problems of character recognition were primarily problems of tolerances and reliability. Despite the success of the joint industry technical committtees in designing characters to optimize machine readability and ease of printing, allowable printing tolerances and document mutilation still require very sophisticated reading equipment. The allowable printing tolerances also require relatively high quality and closely controlled printing as well.

The printing tolerances, effects of mutilation, and component tolerances all combine to introduce noise into the reading system. This noise is statistical in nature, resulting from variations in a large number of factors, such as variation in inks, character dimensions, amount of ink deposited, location and angular orientation of the characters, document speed, head-to-check spacing, ink splatter, offset, voids, smears, and many others. Understanding of the ways in which these factors affected the reading equipment was obtained through theoretical mathematical studies, detailed measurement and inspection of large volumes of printed samples, experimentation with reading methods, and interchange of information in the technical committees.

The importance of accuracy in reading bank documents means that reading equipment must be capable of determining that amplitude of the noise factors at which the chances of reading incorrectly are significant. In such cases, the equipment rejects the document rather than take a chance of making an error. Thus, rejection

circuitry is also an integral part of the reading equipment. In developing the Sorter-Reader, the recognition circuitry went through three complete phases. The first phase consisted of the development of a complete operating breadboard model of the character recognition circuitry using conventional vacuum tubes. The second phase was a completely transistorized breadboard model and the last phase was the final transistorized circuitry on printed-circuit cards as installed in the prototype sorter-reader. All three phases were completed at the Research Center.

In addition to the document-handling and character-recognition aspects of the sorter, there was a considerable amount of interesting and creative work done in the areas of control circuitry, styling, human engineering, and logical design. All of this work also involved the utilization of diverse skills and facilities and went through phases of development similar to the ones described above.

Although the project involved a greater financial expenditure than anticipated, it was completed on schedule, and the Sorter-Reader met, and in a number of areas surpassed, the product specifications of performance and reliability.

In summarizing the Sorter-Reader case history, there are several points I would like to mention which I believe distinguish this interesting example of "research in action."

The Sorter-Reader is a machine developed in a competitive commercial atmosphere where the customer called the shots. The result is a rare example of a non-Government group (ABA) succeeding in establising an industry-wide standard without eliminating the basic freedom and flexibility of competitive enterprise.

The development of the Sorter-Reader is an example of the dynamic power of a well-established and diverse industrial research center which, although established primarily for long-term technical development, can be effectively used for a short-term product-development project.

The Sorter-Reader is an example of research and development work that was accurately scheduled and successfully implemented. Finally, the Sorter-Reader is an example of the benefits to be derived from labor-saving automation in the field of commercial data-processing equipment.

THE EVALUATION OF SCIENTIFIC PERSONNEL

GILBERT KELTON

Executive Assistant to Director, Philips Laboratories
A Division of North American Philips Company, Inc.
Irvington-on-Hudson, New York

Evaluating scientific personnel is a continuing and serious management function and one that is generally a never-ending problem. A few years ago I had the opportunity of discussing this problem while visiting a number of R & D laboratories and plants throughout the country for the purpose of making an informal survey of technical management policies and procedures. Here I propose to highlight some of the major facets of the problem, as they were revealed in that survey. It is observed that present-day performance evaluations, for the most part, are arbitrary, inadequate, and unreliable, resulting in "market value" appraisals of technical personnel. However, the intensified interest in evaluating scientific productivity indicates that greater understanding and keener insights will result, making possible more reliable evaluations.

Whom Are We Evaluating?

One of the most important factors in the process of evaluation is the consideration of who is being evaluated. Although the answer may be offered that we are obviously concerned with scientists, I firmly believe that a better answer would be that we are

appraising human beings who happen to be scientists. I stress this point because of the great tendency to set the scientist apart from all other mankind, thereby creating the impression, *ipso facto,* that he is a vastly different species. This concept prevails in so many organizations and communities that one can say that it is virtually a universal philosophy. It implies that the scientists's desires, needs, feelings, reactions, motivations, and for that matter, all of his senses, emotions, and instincts are completely different from those of other human beings. Nothing could be further from the truth! The scientist is a human being first and an individual trained in a scientific discipline second. Being human, his senses and emotions are not basically different from those of others. His needs and desires are similar. The difference, if any, lies only in degree, and even here one must be careful not to consider that a minority represents the majority. The antiquated, stereotyped idea that a scientist is an absent-minded, unkempt, bespectacled, antisocial person ceaselessly working in a laboratory within an ivory tower who wants nothing more out of life than to discover the fifth dimension has misled society long enough and should be obliterated from the scene. Instead, it would be realistic, in this day and age, to view the scientist as does Steele,[1] who states that "one can safely say that a large majority of them [scientists] are very intelligent, highly trained individuals with strong professional orientation and a great desire to participate in the advancement of knowledge." The scientist is an individual who wants recognition, advancement, freedom, and security, and who wishes to live on a par with other persons of equivalent education and training in the community. But since the same may be said for lawyers, politicians, artists, musicians, and a host of others not in a scientific field, it is well to recognize that the nature of the scientist being evaluated is not unlike that of persons in other professions. It is only his function as a scientist that differs, and it is his fulfillment of that function which is to be evaluated. This leads us to consider what qualities of a scientist are to be evaluated.

What Are We Evaluating?

If one were asked to evaluate the performance of automatic-screw-machine operators on an assembly line, several quantitative measures would become apparent, such as the number of pieces turned out in a given period of time, the set-up time required, the amount of wastage, the attendance records, and even time-motion studies on the movements of the individuals performing the operation. While there are other, more intangible factors that could be added to the operator evaluation, there are sufficient measurable criteria. Scientific and engineering activities on the professional level however, by their very nature, do not lend themselves to simplified quantitative measurements of the performance of personnel. Therein exists the problem. In fact, there is still much haziness with regard to effective measurement of the work of a scientific organization; evaluation of particular members of its technical personnel is still more vague. Suits[2] has pointed to this and, in reference to research laboratories, has added that "some progress is being made in identifying the elements of output of a research organization, and by the example of these methods we may one day learn how to measure the performance and productivity of the individual research scientist." That day has not yet arrived.

The characteristics stated most frequently by technical managers and personnel directors during my visits to over 30 organizations can be summarized as follows.

(*1*) Knowledge of the subject
(*2*) Initiative
(*3*) Originality (and creativity)
(*4*) Responsibility (and dependability)
(*5*) Good judgment
(*6*) Leadership ability
(*7*) Cooperation (and ability to get along with others)
(*8*) Attitudes

(*9*) Professional integrity and honesty
(*10*) Personality (and temperament)
(*11*) Ability to communicate effectively
(*12*) Publications, patents, and inventions
(*13*) Honors, awards, professional society affiliations

No order of importance is intended, nor is the list all-inclusive. However, these were cited by an overwhelming majority of those with whom the factors were discussed, and one finds them to be the characteristics which appear most often on organization rating sheets. Since these appear to be, for the most part, the elements to be evaluated, three considerations presents themselves. First, it is assumed that these qualities represent the measure of effectiveness of a scientist. Second, it is assumed that these qualities (or rather, the words by which they are usually described) mean the same and are therefore always interpreted the same way by all individuals responsible for evaluating. Third, it is assumed (or at least hoped) that these are measurable qualities; thus many rating sheets provide a scale for each of these traits or characteristics.

To determine whether these factors adequately represent the effectiveness or performance of a scientist one would have to determine first the nature and degree of productivity of organized research and development activities, develop a norm of such productivity, and then, using it as a criterion, measure how each of the scientist's traits contribute to the output. In other words, one might evaluate a scientist in the light of a preconceived plan of what he is supposed to do. However, it has been recognized that the output factors of research and development are not altogether clear and are indeed difficult to determine.[2] Rubenstein,[3] in a discussion of recent programs designed to study the elements and factors leading to increased scientific productivity, states that "it is difficult to obtain reliable data on the input-output characteristics of research and development." There is still much to be learned concerning the human characteristics and their relative

contribution to technical performance before they can effectively be utilized in rating scales for scientists.

Do the characteristics mean the same thing to all persons? Discussions with technical supervisors and personnel administrators reveal rather wide differences in the connotation of the characteristics. For example, "creativity" is a much-mentioned word today, as was the word "challenge" the key word just a few years ago. Spencer[4] views creativeness as a composite of five qualities: compulsiveness, intelligence, visual imagery, controlled imagination, and a spirit of rebellion, all in an undefinable state of balance and interaction. Engstrom[5] views creativeness as the "creation of new understandings, new principles, new products, and new services." He adds that "creativeness coupled with vision to give the creation objectivity makes for great research." He then points out how some others define the term, namely, "ability to create plus the desire to do it," and "a combination of drive and enthusiasm which leads a person to look upon his work neither as a romantic adventure nor as a paid job, but as an opportunity for a lifetime career," and "a combination of initiative, ingenuity, and imagination, together with intellectual honesty and industriousness." Carver[6] prefers to explain rather than define creative thought. He feels that "an idea or a theory [which] comes from completely inadequate data or from data so scattered or hidden that routine methods of thinking would never have assembled them to bear upon a particular idea" is creative. He adds that "it is not necessary for the idea or the hypothesis to be correct or even new." He points out that if a new theory is developed to replace a previously accepted theory or idea this is constructive rather than creative thinking. Hence, where Engstrom emphasizes "newness," Carver almost rejects it!! Personally, I would be inclined to say that the scientist in basic research is a discoverer, while the design and development engineer is a creator. With this concept, scientific efforts which produce negative results would still be considered as discoveries though not necessarily as creations. With-

out belaboring the situation, it can be seen that there exists a large number of views and opinions relative to the determination and measurement of this particular characteristic, and the same may be said of many other characteristics on the list. Hence, ratings on these qualities may vary in accordance with the rater's definitions and concepts of the qualities.

Recent studies indicate that measurement of these qualities with a high degree of reliability or validity is extremely difficult. Quinn[7] made an extensive study of about 200 publications and interviewed 60 top research and operating executives in the electronics and chemical industries on techniques used for measuring the results of their R & D programs. It is significant to note that only about 15% rely on quantitative devices for evaluation. In discussing aspects of research output, Quinn considers two types of contributions, the technical and the economic, which should be evaluated separately. This same view is also depicted by Wilson.[8] Both men have found that, because of the difficulty (virtual impossibility) of quantitative measurements, common practice is to rely on qualitative evaluations based on subjective judgments. Strauss[9] states that "a true appraisal of an employee is a very subjective matter that takes into account many elements not found on most rating forms." Strauss then suggests a subjective system divorced from salary adjustments. While there may be several factors that lend themselves to quantitative assessment, e.g., those described by Shockley[10] relative to the scientific publications, most of the characteristics do not lend themselves to reliable and valid measurements.

In the foregoing paragraphs, we have seen that the entities evaluated may or may not be relevant, and that the evaluations are necessarily subjective and qualitative in nature and greatly dependent upon the rater. Therefore, let us consider the people who are evaluating the scientist.

Who Is Evaluating?

The evaluation process varies from organization to organization. Job analysis vs. performance, paired comparison performance, Gaussian distribution order of merit, individual scientific performance, cost vs. scientific performance, and several other techniques or combination of these techniques seem most prevalent. The ratings or evaluations are most frequently conducted by technical supervisors, personnel administrators, technical managers, or, in some instances, committees or groups of such individuals. It should also be borne in mind that these individuals are rated by similar persons a notch above them. Since these are the people who are obligated to make the necessary subjective evaluations of their subordinates, it is assumed that they are prepared to make reasonably valid judgments in these matters. Unfortunately, this is not always the case.

The supervisor, regardless of his specific title, is, in a sense, a manager or is acting in a management capacity. It is assumed that he knows his own job and the functions of those on his staff, and therefore that he can evaluate their performance relative to certain known and established goals. It is my contention that this assumption is not valid. In a portion of a survey conducted by Milberg,[11] one of the implications was the "inability on the part of managers to define or describe the research-management task." He noted that the answers to queries "were most frequently put into self-oriented terms" and that the manager "cannot clearly distinguish between technical and administrative characteristics and between organizational and scientific needs." From my own observations[12] at various organizations, I found that the majority of technical managers was somewhat lacking in the qualities that are supposed to be desirable. If these people rely on "introspection to explain their own status," as Milberg indicates, and use themselves as criteria for evaluating others, then the validity of their evaluations is highly questionable. In a very

limited study undertaken by Schooley,[13] an attempt was made to determine the reliability of estimating the scientific potential of a dozen individuals who were recent B.S. graduates at the early part of World War II. When estimates based on all data available at the time of hiring were compared with actual performance over a twelve-year period, it was found that predictions made by drawing the names out of a hat were as good or better than those made by three experienced scientists! Predictions made by three competent personnel administrators and by three competent secretaries were not quite as good as pulling the names out of a hat! Of course, the technique used for measuring actual performance and comparing it with the predictions is immediately open to question. Be that as it may, I cite this limited experiment merely to emphasize the fact that supposedly experienced and qualified people have difficulty in evaluating scientific personnel.

While I do not believe that the situation is quite so dismal as the above example would indicate, there are strong indications that those who are presently responsible for such evaluations are in need of more guidance and instruction from management and require more information which may some day be provided by further studies in the R & D management field.

Why Evaluate Scientific Personnel?

Because of the difficulties involved in the evaluation of scientific personnel, one may be inclined to dispense with all appraisals. Obviously this cannot be done, for society itself makes and demands assessments of everything. Let us consider some of the major intended purposes of such evaluations of scientific personnel. Two values are involved: the value to the scientist (employee) and the value to the organization (management).

From the point of view of the employee, an evaluation should provide him with a picture of his worth to the organization. It should answer the question, "How am I doing on the job?" In

addition, it should serve as a motivating device, point up previously undiscovered talents and weaknesses, and show to the employee the deep interest of management in his progress.

As viewed by management, the evaluation should, as in the case of the employee, depict the scientist's value to the organization. Additional areas in which it is useful to management are in arriving at salary adjustments, promotions, and other rewards, in making proper assignments; in providing counseling and training; and in overall program assessment.

Since there exists a duality in the evaluation concept, it should be considered, as does Myers,[14] to be a "two-way affair." Hence, it is extremely important that all evaluations be discussed thoroughly with the individual being rated. Because of the subjectivity of the evaluation, ample opportunity should be given to the ratee for comments, explanations, and even rebuttal. Moreover, by discussing the assessment directly with the individual, a further opportunity is provided for management to outline its goals and objectives and indicate how it expects the scientist to participate in the achievement of those goals. In like manner, the scientist should be free to express his own goals and objectives. In this way, there is a greater possibility of deriving maximum benefits from the scientific personnel on the staff.

However, I suspect that these practices are not widespread. Steele[15] states that "the most common use of merit rating in research is as a basis for pay increases. In fact, in many cases there is a tendency to make this the principal or even the only use." I not only concur, but have found that there is one technique that is more prevalent than others. I term this the "market value" approach. It works in the following way. Suppose you brought your automobile to a dealer for purposes of sale or trade, thereby requiring an evaluation of your car. The appraiser examines the vehicle, some appraisers being more thorough than others, and then he consults some standard Blue or Red Book which lists a current standard market value for the automobile. If it is a

"cream puff" type of car, that is, one in superb physical condition by all outward appearances, you may receive $50 to $100 more than if it were in an average condition, the variations being well within 1 or 2% of the total allowance offered. This is no secret, and everyone who has ever traded or sold his car to a dealer recognizes this procedure and accepts it for what it is worth.

This "market value" approach is also used in the evaluation of scientific personnel. The evaluator makes a subjective appraisal and then, in place of the automobile Blue or Red Book, he turns to one or more of the national, local, or organizational salary survey reports to determine the "going rate" for similar types of scientists. Here too, the final assessment is usually within 1 or 2% of the standard market value. The irony of the situation comes to the forefront when the evaluators then judge a scientist's ability on the basis of his monetary standing on the scale! Just as it has been said that "one may be judged by the company one keeps," he is often judged by the salary bracket in which he has been arbitrarily placed. This brings me to the final aspect of the problem which I should like to discuss, that of rewards based upon these evaluations.

What Are the Desired Rewards?

Since, in practice, most evaluations are conducted primarily for purposes of salary adjustment, one may seek to determine if monetary rewards are desirable. If my assumption that scientists have much the same desires as those in other professions is correct, then monetary rewards may be highly important. On the basis of numerous discussions with scientists at all levels, I am inclined to believe that monetary rewards are the most sought after, management authority being a close second. Results of some studies seem to support this view. Bryson[16] discusses scientists in industry and says of rewards, "Prestige, pay, and power; these are the three obvious and measurable rewards that men work for. Other motives are

beyond the reach of the administrator and are determined mostly by accident." On the basis of a four-year survey, Stein[17] prepared a list of twelve rewards in the order selected by several hundred research scientists in industry. Of the top four selected, two were monetary rewards and two were administrative (which indirectly would infer a monetary reward plus authority). Stein attributes this to the fact that the study and survey related to scientists in industry rather than in academic or nonprofit institutions, where the listing might have been different. Siepert,[18] who conducted a natonal survey involving over 20,000 scientists in government and private industrial laboratories, found that "two thirds of the government scientists and engineers are dissatisfied with their prospects for salary advancement." He adds that one fourth of those in private industry registered the same complaint. Dr. Clifford C. Furnas, Chancellor of the University of Buffalo, has stated that, although he had thought that "high prestige, good working conditions, and congenial relations" were highly important to engineers, he has noted that they will change company affiliation for an increase in salary.

Now the question is whether the techniques of evaluation lead one to reward the scientist properly. The "market value" approach, which is so widely used, is far from satisfactory. Once placed in a particular bracket, it is merely a question of advancing in small increments almost devoid of merit and performance considerations. It is not easy for a man to move out of a given bracket. As Shockley[10] points out, "statistically, an increase of 30 to 50% in productivity is necessary for an individual to obtain an increase in salary of 10%." Inasmuch as such an increase in productivity is rare, it is not too likely that salary increases will be 10% or higher.

To be sure, I fully realize that money alone will not serve as a satisfactory reward for scientific personnel. Other rewards might include promotion to a position involving increased authority and responsibility, open praise and encouragement from management, granting increased freedom to undertake programs, to pub-

lish, and to attend professional society meetings, and the granting of special privileges and extra fringe benefits. But if these are to be meaningful, they must be awarded on the basis of fair evaluations. The effectiveness with which evaluations are administered directly reacts upon the morale of the organization. It is also a reflection on the overall management and administration of the organization. The fact that so many engineers and scientists in industry are "more frustrated than satisfied," as corroborated by the survey made by Moore and Renck,[19] indicates that management might well engage in some self-evaluation with a view toward rectification.

Whither Evaluations?

In reviewing the situation, I see much hope for great improvements in the evaluation of scientific personnel. These improvements will be achieved by virtue of the pressing need and the growing concern of management coupled with serious endeavors to seek new solutions to the problem. The following are a few manifestations of progress.

1. The realization by management that present evaluation techniques are far from satisfactory.

2. The intensified efforts applied to research and study of the scientist in his role in society as well as in his role in an R & D setting.

3. The growing number of studies related to the factors involved in scientific productivity and possible aids in their measurement.

4. The awakening of the scientist himself in viewing his new technico-socio-economic role.

While I know of no panacea for the immediate situation, I should like to offer the following suggestions for management consideration.

1. For the present, accept the fact that evaluations of scientific

personnel are necessarily subjective in nature and judge them in that light.

2. Recognize the fact that evaluations of scientific personnel can be used for more than determinations of salary adjustments.

3. Impress upon evaluators the seriousness and far-reaching effects of an evaluation, in an effort to insure adequate time, proper approach, and meaningful and unbiased results.

4. Consider evaluation as a continuing process rather than an act performed once or twice a year, in order that evaluators may be constantly alert and aware of those they are evaluating.

5. Endeavor to provide overall guidance with reference to goals and objectives so that subordinates can ascertain their roles in achieving the desired results.

6. Utilize the two-way approach to evaluation, explaining the results of the evaluation to the scientist and offering him the opportunity of appraising the organization.

7. Recognize the scientist as a normal but highly intelligent human being, and use all available types of rewards to display appreciation for his efforts.

8. Seek to improve the overall evaluation process by self-appraisals and by fostering and encouraging further research and experimentation relative to evaluation processes.

References

[1] Steele, Lowell W., "The challenge of research management" *Ind. Eng. Chem.,* **49,** 109A (1957).

[2] Suits, C. Guy, "The manageability of scientific research," *The Management of Scientific Manpower, A.M.A. Management Rept. No. 22,* 1958.

[3] Rubenstein, Albert H., "The technical man—prologue to technical productivity," *Ind. Eng. Chem.,* **51,** 10 (1959).

[4] Spencer, G. J., "Characteristics of the creative engineer," *Mech. Eng.,* **80** (1958).

[5] Engstrom, Elmer W., "What industry requires of the research worker," *Proceedings of the Third Conference on Industrial Research,* King's Crown Press, New York, 1953, p. 121.

[6] Carver, Emmett K., *Organization, Personalities, and Creative Thought*

on Human Relations in Industrial Research Management, Columbia University Press, N. Y., 1957.

[7] Quinn, James B., "Measurement of research accomplishment," *Proceedings of the 11th National Conference on the Administration of Research,* Penn. State Univ. Press, University Park, Pennsylvania, 1958, p. 66.

[8] Wilson, A. H., "The assessment of the work of a research laboratory," *The Direction of Research Establishments,* Philosophical Library, New York, 1957.

[9] Strauss, Daniel J., "A subjective merit review system," *IRE Trans. on Eng. Management, 5,* 141 (1958).

[10] Shockley, William, "On the statistics of individual variations of productivity in research laboratories," *Proc. IRE,* **45,** 279 (1957).

[11] Milberg, Stanley H., "Selection and development for research management—views of managers and some implications," in Livingston, R. T., *Human Relations in Industrial Research Management,* Columbia Univ. Press, New York, 1957, p. 80.

[12] Kelton, Gilbert, "So you want to be a technical manager," *Ind. Labs.,* **10,** 112 1959).

[13] Schooley, Allen, "Is the yardstick for estimating individual engineering and scientific potential reliable?" *IRE Trans. on Eng. Management, 3,* 42 (1956).

[14] Meyers, Wilber C., "Evaluating the research applicant: a two-way approach," *The Management of Scientific Manpower, A.M.A. Management Rept. No. 22,* 1958.

[15] Steele, Lowell W., "Personnel practices in industrial laboratories," in Livingston, R. T., *Human Relations in Industrial Research Management,* Columbia Univ. Press, New York, 1957, p. 349.

[16] Bryson, Lyman, "Researchers in industry," in Livingston, R. T., *Human Relations in Industrial Research Management,* Columbia Univ. Press, New York, 1957, p. 129.

[17] Stein, Morris I., "Creativity and the scientist," *The Direction of Research Establishments,* Philosophical Library, New York, 1957.

[18] Siepert, Albert F., "The Attitudes and motivations of scientists and Engineers toward their jobs," *Proceedings of the 11th National Conference on Administration of Research,* Penn State Univ. Press, University Park, Pennsylvania, 1958, p. 31.

[19] Moore, David G., and Richard Renck, "The professional employee in industry," *J. Business,* **38** (1955).

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